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DESIGN ASPECTS OF ZEPPELIN OPERATIONS  
FROM CASE HISTORIES

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**ABSTRACT:** This paper deals with some widely held beliefs concerning the practicability of rigid airships in air carrier operations. The paper shows, by a review of past operational experience, and some basic aerostatic theory, their actual record and the reasons for their demise. Problems of atmospheric density and temperature variations, meteorological factors, aerodynamic stability and control, and mooring difficulties are discussed and related to actual case histories. Structural and flight efficiencies are compared to airplane efficiencies for airplanes contemporary with the zeppelin as well as modern designs. The difficulty of supporting new, commercial airship developments on an economic basis is made clear.

"In the development of human flight the zeppelin episode could only have been a very brief one". So wrote the master mariner of airships, Hugo Eckener, with respect to air carrier operations. Because reference books, semi-professional journals and current airship enthusiasts have published a great deal of mis-information about bouyant aircraft, it is the purpose of this paper to put on the record of this workshop some physical laws and design factors that establish the truth of Eckener's observation.

Ship Analogy - Sir George Cayley appears to have started the analogy with surface ships by suggesting that airship lift be subdivided into multiple compartments for greater safety. C. P. Burgess wrote that because rigid airships had this feature, they could lose one or more lifting cells without endangering the airworthiness of the ship.

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the utilization of volume aboard a ship and an airship. In Fig. 1 it is seen that it is almost impossible to overload a ship with most industrial products, -only solid materials and ore can do that. Generally, the stability of the ship becomes the limiting factor, not the load which may be placed aboard. In contrast, the passenger and cargo space on the airship is so small as to be almost unrecognizable. As an Englishman has put it, "The wisdom is questionable, of creating an airship as large as the MAJRETANIA for a load only so large as a lorry can carry".

Before leaving this analogy, it is necessary to point out that only captive balloons operate lighter than air. In normal operation, an airship is not lighter than air. Like a ship, it is equal in weight to the weight of the fluid it displaces. Balloons, and all airships, which are really dirigible balloons, should be called bouyant aircraft, and the term 'lighter than air' eliminated as part of the myth surrounding the subject.

### AEROSTATICS

Eckener reminds one that every airship landing is essentially a balloon landing. Misunderstanding concerning the nature of balloon flight began with the first public notice, the 23 August Proclamation of the French Government, issued, "so that alarm be not occasioned to the people". It spoke of balloon experiments then in progress and revealed the operating principle as "filled with inflammable air" a balloon will "rise toward heaven till it's in equilibrium with the surrounding air". Ever since, most people believe that a balloon will rise until it is in equilibrium with less dense air at higher altitude, and conversely, that a descending balloon will sink until it is in equilibrium with lower, more dense air. In fact, aerostatic lift is unstable lift. A light balloon will continue to go up and a heavy one down, until the pilot valves gas or drops weight, or the balloon, on its way up, passes the height at which its bag is full, known as pressure height, and either blows-off gas through its overpressure valves, or bursts. This physical fact is responsible for the expenditure of both gas and ballast on every flight. In operation, an airship must sacrifice almost 1% of its gross lift for every 100 ft rise in altitude, and must carry a minimum of 3% of its gross lift in the form of ballast to prevent inadvertent descent at inopportune times. In practice, its lifting gas is assumed to be about 95% pure (ie., diffused 5% by air). Thus, a commercial airship must sacrifice about 13% of its cargo capacity to fly at minimum altitude (1500 ft) with minimum safe ballast. No other vehicle ever seriously considered for commerce is so inherently handicapped.

Altitude - Fig. 2 shows the aerostatic effect on design if an airship

were considered for transcontinental flight. For scheduled, instrument flight over eastern USA, the FAA requires a minimum cruising altitude of 8000 ft, and over western USA 16,000 ft. The figure shows the increases in diameter, frontal area, and volume necessary to achieve various cruise altitudes, compared to a sea level balloon having the same lift capability. Alternately, the lower block shows the effect on lift capability if the volume is kept constant and the design is used at the various altitudes. This block explains the extreme difficulty all airships have had in crossing the United States in the past, as they were all sea level designs. The SHENANDOAH flew so low she knocked off her trailing wire antenna 'fish' at 2200 hrs near El Paso. The GRAF did the same thing near Tours on the return maiden flight, also at night, and carrying passengers! The AKRON, eastbound, had to jettison 6 tons of fuel and her onboard airplanes to proceed beyond Phoenix, and was then so short of fuel she couldn't make it back to Lakehurst non-stop.

None of the historic airship flights would have been sanctioned under modern airways regulations, yet these flights are recalled by current enthusiasts to extoll the capabilities of zeppelins. It should be noted that the figure represents static lift effects only. A larger airship would require still greater volume increase to carry the larger engines and greater fuel and ballast load of the larger, high level design.

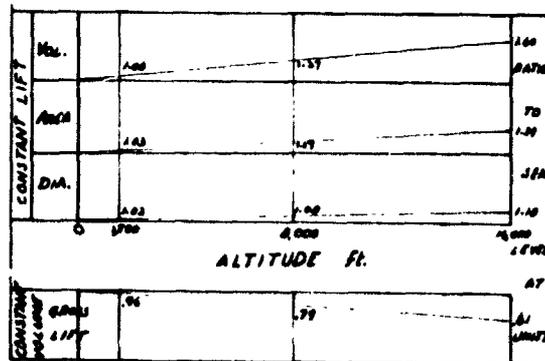


Figure 2. Static Effect of Altitude

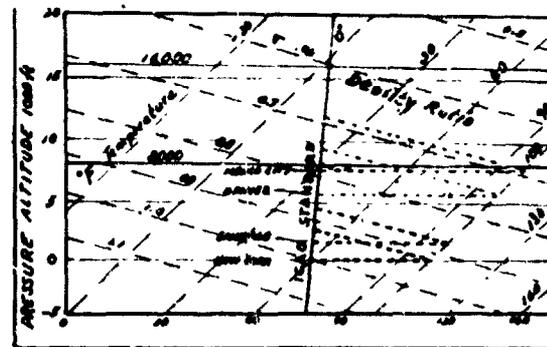


Figure 3. Atmospheric Effects

The real world has a variable atmosphere and cities are located at various altitudes and climates. Fig. 3 is a standard air chart which has certain selected cities spotted on it at their respective altitudes. It is seen that an airship designed for eastern USA (8000 ft design altitude) could not operate into Denver, at design gross weight if the ground temperature exceeded 85°F, although Denver's altitude is but 5280 ft. The same would be true at Mexico City, elevation 7347 ft.

whenever the temperature exceeded 42°F. Only the 16,000 ft design would be practical for both places, even though the Rocky Mountains would not have to be crossed from the eastern seaboard, for either destination.

**Superheat** - This is the amount of increase of gas temperature above ambient air. Superheat develops most noticeably when the airship is moored out on the field on a sunny day. Even at Santiago, elevation 1675 ft, the airship will be at 7,400 ft density altitude if 40° of superheat is allowed to develop on a 100°F day. A sea level design airship with full cells will blow off gas equivalent to 18% of its gross lift under such conditions. This happened to the GRAF at Los Angeles. As the field had no refilling facilities, the GRAF was so heavy at take-off, she left without ballast and made it over the telephone wires at the end of the field with 3 ft to spare. Eckener mentions a 'cat-walk' crew, whose duty it was to step off, or back onto a moored zeppelin, depending on changing superheat as clouds or rain showers went by. Larger zeppelins will require that the field have gas, water and fuel pumping facilities to maintain the airship at correct equilibrium under changing conditions. The AKRON experienced this situation at Parris Is. Marine Base, and the MACON at Opa-Locka. In both episodes, alternate rain and sun aggravated the troubles, as rain soaked covers may add 10% to the gross weight of the ship.

**Rain, Snow and Ice Loads** - If extra gas is added to permit take-off with a load of rain, snow or ice on the cover, this gas will be blown-off when the ship reaches design altitude. Cold weather will normally allow take-off, whereas in hot weather the gas cells may become full before the extra lift to carry the load is obtained. While moored, snow and ice may cause high local structural stresses at the horizontal fin attach points. Nobile recounts brooming for two days to prevent snow accumulations from buckling his hull at these points. Andree's log books show his balloon suffered acutely from snow and ice loads in flight, and they leave the recommendation that means be developed to heat the cover and prevent such accumulations. Nobile's controls froze tight on his return from the North Pole. His tragic crash is attributable indirectly to having to stop the ship while the jammed controls were freed. However glorious the record of the German passenger zeppelins, they never attempted a North Atlantic crossing in the winter season. Only a few years later, green crews flew combat planes over this route year 'round. De-icing remains a development of large proportion facing those who would resurrect the zeppelin.

#### AERODYNAMICS

Knut Eckener claimed that airships flew naturally, unlike airplanes

which depended on some trick to keep it in balance. The force center comparisons, shown in Fig 4, indicate the airship may be the trickier of the two. In airplane configuration terms, the airship is a 'tail-less' design, meaning the tail control surfaces are carried on the wing itself, -the wing being the hull of the airship. While the center of pressure (c.p.) and the center of gravity are virtually coincident on an airplane, the c.p. is far forward of the c.g. on the airship when it enters a gust. The airship has a third force center, the center of buoyancy (c.b.) located high, but directly above, the c.g. This arrangement provides a stable restoring moment whenever the hull develops lift. It is seen that the low slung engines of the airship always produce a pitch-up. C.P. movement on an airplane is expressed as a percentage of the length of the wing cord. On an airship, it is a percentage of the length of the entire hull. Tailless airplanes cause design control difficulties; so does the airship. The inter-relationship of forces about these three centers apparently require a great deal of experience for the pilot to assess correctly. For instance, a heavy ship will be flown dynamically in a nose up attitude. But an airship at neutral buoyancy, trimmed statically nose heavy, will appear to fly in the same attitude. Consumption of the fuel and water ballast causes the c.g. to rise, thus reducing its power to provide stable restoring moments. A light ship flies and handles differently than a heavy ship.

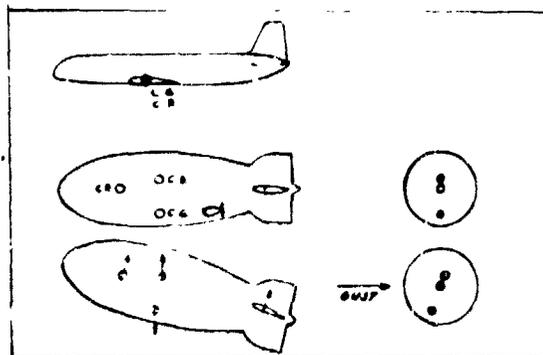


Figure 4. Force Center Comparisons

that it took 25 seconds to move the LOS ANGELES elevator through full travel, and that Norway was proud of his solution for the R-100 which only permitted the full strength of the helmsman to move the control  $3^{\circ}$  initially. Then, as the ship responded, additional deflection could be applied. Full deflection took about 30 seconds! Norway recalls passing thru a squall at night, near Montreal, when the ship was tossed upward 3200 ft into the clouds, spun  $92^{\circ}$  in direction, and

Controls - The destabilizing force always produced by gusts on the forward hull is countered by the large control surfaces. Their movement has been a field for development of design philosophy, if not for satisfactory solution of the problem they present. The problem is that rapid movement of the surfaces tends to produce forces so high as to endanger the integrity of the hull. On the other hand, slow motion produces very sluggish control response.

It sounds incredulous to learn

pitched nose down 35°, all in less than a minute. Actually, Norway's statement proves the ship was actually uncontrollable under certain conditions. Both the SHENANDOAH and MACON experienced moments when the rudder was applied one way and the nose moved initially in the other. The SHENANDOAH just missed a mountain at night. On the MACON, the forces produced under this action carried away her upper fin. Because the airship has a very low thrust to weight ratio, and is sluggish in response to its controls, it can hardly avoid being carried above pressure height in a developing thunderstorm. It then blows-off its gas, or overpressures and bursts its gas cells, leaving the airship heavy as it encounters the corresponding down current. Either the structure fails, as it did in the case of the SHENANDOAH and the DIXIE or the ship is left short of fuel and ballast with which to reach its destination. Because the trim of the airship and the forces developed are so interrelated the pilot may easily make an error of judgement. The MACON was 'light' when her fin ripped off and deflated her aft cells, due to the action of a violent down and side gust. Without steering control and hanging tail low, the pilot dumped ballast heavily. The MACON then rose above pressure height to 4850 ft and stayed there 16 minutes, blowing off gas. When it finally grew 'heavy' and started down, it went all the way down into the sea.

Airships driven into warmer air tend to sink until their gas temperature normalizes with the ambient air. The reverse is true when driven into colder air. Under such conditions, the airship may at first balk at climbing into warmer air, or descend into colder air. The AKRON spent several hours cooling off her gas before she would descend into the cool air overlaying San Diego on her first trip west. Because of such 'tricks' airship schedules may only be set to the day, steam ship schedules to the early or late tide, while airline schedules may be set to the hour, as Scandinavian Airlines demonstrated when pioneering the North Polar route from western USA to Europe.

Systems have been proposed to eliminate the valving of gas, by various means, or to recover the weight of fuel consumed by water recovery systems placed in the engine exhaust. None of these systems would answer the control requirement for successful penetration of violent atmospheric conditions. The glib answer is to avoid such conditions. If the incident of violent weather coincides with the arrival of the ship at her destination, the answer is no longer satisfactory. Alternate bases, criminally lacking in the past, must be provided in any serious plan of the future.

#### MOORING

A previous section discussed mooring problems associated with changing

lift due to temperature variations and precipitation. This section will touch on mooring problems connected with wind. The problem dates back to the first involuntary free flight of a Montgolfier balloon, their second of 600 cu ft capacity, when the wind tore loose the tethering lines. A few days later it destroyed their 23,000 cu ft balloon, prepared for a demonstration before the Royal Academy. Both Eckener and Lehman had their mooring accidents. The mooring system developed by the US Navy appears to represent the highest state of development of any, but it is desired to question one feature of this development, the stern beam car. Fig. 5 shows this car in position. It rode out of the dock athwartships, then transferred to the rails of the mooring circle, until the airship was headed into the wind. Then it was replaced by a lighter 'riding-out' car which allowed the airship to rotate into the wind with her nose secured to the mast at the center of the mooring circle. The operation was reversed for docking the airship.



Figure 5. Stern Beam Car

The stern car was in use in February 1933, when it was noted that strong cross winds were heeling the AKRON 6° from vertical. An instant later the lines tore sections of Frame 35, 17 and Zero out of the ship. Frame 17 was damaged on the MACON from thermals while crossing Texas on a sunny day, and is also the frame from which the upper fin of the MACON separated, the day the MACON was lost. With this restraint system the wire stays from the stern car do not pass into the center line of the ship, while the nose is restrained at the center line. How much strain did Frame 17 absorb during the undocking and docking operation, and to what degree was this system of docking responsible for the successive failures of Frame 17? Perhaps the floating hangar system originally used was the optimum system.

#### STRUCTURE

Fig. 6 shows the differences in frame design used on the German and American airships. Fig. 6a shows the radial, wire braced Zeppelin Co. type frame. Fig. 6b shows the Goodyear design, an integrally braced, deep triangular section, built-up girder ring. The fins of the AKRON-

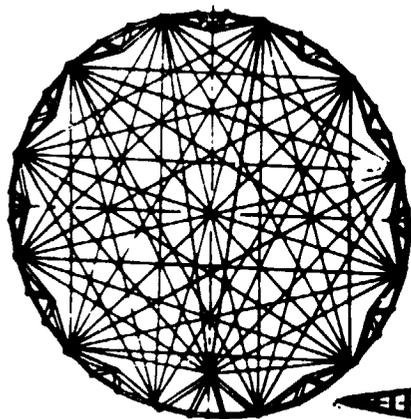


Figure 6a.  
Wire Braced

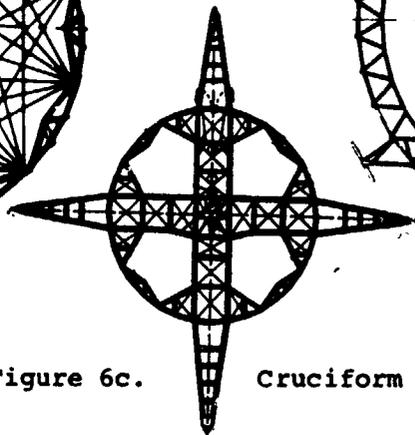


Figure 6c. Cruciform Tail

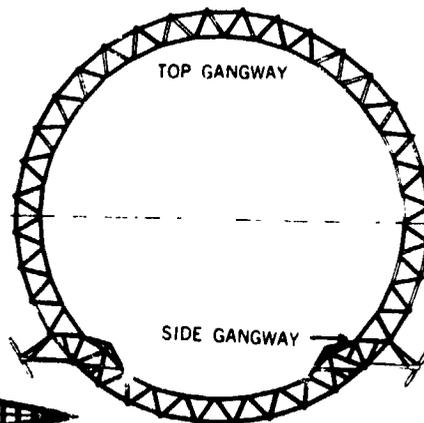


Figure 6b.  
Integrally Stiff

MACON were cantilevered from such rings. The side loads developed by the fins due to cross winds while mooring would be transferred thru these rings to the wire stays of the stern beam car. In contrast, the fin spars on Zeppelin designs passed right thru the hull, in what is called 'cruciform' design. Fig 6c shows how well braced the Zeppelin fins were into the frames. The difference in design has occupied many words of testimony, and any new design would revive the discussion all over again.

#### METEOROLOGY

The original French Proclamation of 1783, prophesied that the taffeta and paper machines "will some day prove serviceable to the wants of society". So they have, particularly in the field of meteorology, which has reciprocated by serving all aviation. In WWII, the air transport command adopted 'pressure pattern' navigation, said then to have been developed by the Zeppelin Company. It is astonishing to discover that in 1831 an American mechanical engineer, William Redfield, published a paper entitled "The Law of Storms" and in 1836, gave a set of rules for determining the path of a hurricane and how to avoid sailing into the center of it. An English museum curator, Henry Piddington in Calcutta, read Redfield's papers and soon marketed a "Sailor's Horn Book" enclosing in cover pockets, celluloid guides for the Northern and Southern hemispheres. With these, the knowledgeable ship's captain

could locate on his chart, the center of a storm, whether to run before the storm or detour behind it, and what his sailing time would be. Fig. 7 shows Eckener's use of this knowledge on his delivery flight with the LOS ANGELES, and the maiden flight to the USA in the GRAF ZEPPELIN. His long detours by way of the Madiera, Azores and Bermuda Islands are plain to see. Of particular interest is his return journey in the GRAF, when he deliberately penetrated a front off the east coast of the United States, and based on clear weather reports, planned a great circle route from there all the way home. Instead, his 1,000 extra miles of zigs and zags indicate the kind of weather he actually ran around.

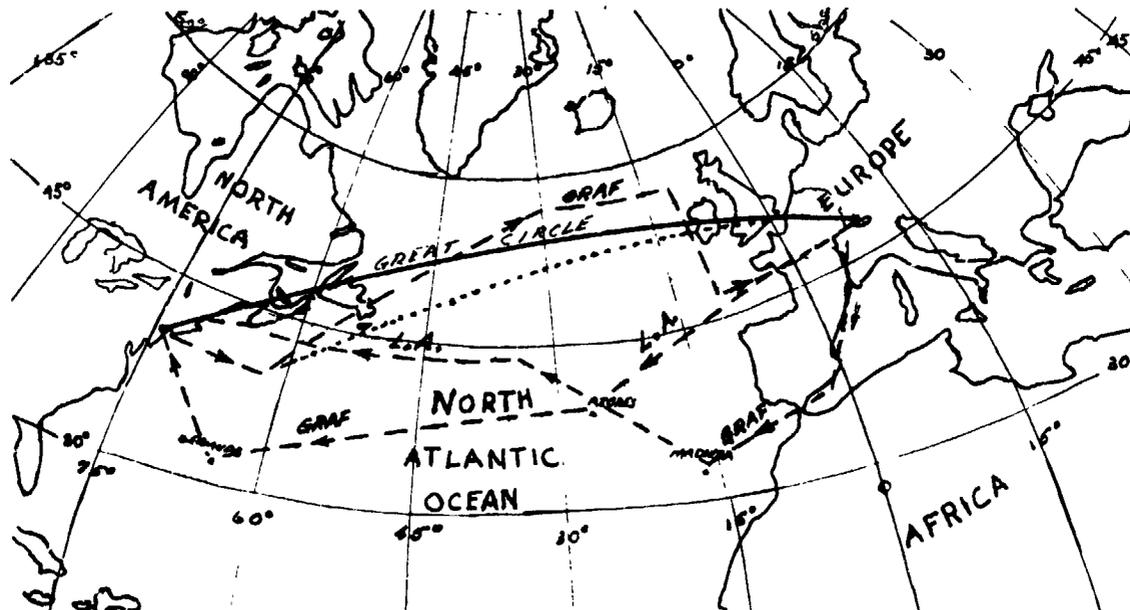


Figure 7. Actual Routes vs Great Circle

In January 1933, the captain of the AKRON detoured around the Great Lakes to land the following day behind a storm that had confronted him the night before when he had tried to land at Lakehurst. American airship captains also learned meteorology, but were guided more by radio reports than by the "Law of Storms". In April 1933, that same captain made several course reversals before choosing one that took him straight into the center of a storm, and eternity. On that night, static had partially blocked his reception of a full weather report. The literature suggests the airship was mishandled on the fatal night. It might be more accurate to admit that zeppelins cannot survive some storms.

There seem to be only two kinds of turbulence particularly dangerous to airships. One is a single violent gust not visibly associated with a frontal passage, or any widely ranging thermals. It is undetectable and experienced before the pilot can do anything. Such a gust appears to have torn the wing off a jet airliner climbing to altitude past Mt. Fuji, and on 12 Feb 1935, one tore the upper fin off the MACON, three miles off Pt. Sur, over the Pacific Ocean on a generally overcast day when violent updrafts are least expected. Another kind of turbulence is associated with frontal passage and air mass thunderstorms. The principal currents are up and down, in clear air or in precipitation, at any altitude, and occasionally, strong horizontal gusts are encountered at the same time. The sequence of zeppelin failure under these conditions has been mentioned previously. Munk, a contemporary of the WWI zeppelin age, analyzed a sample gust of 6 ft per second and concluded that gusts are no more dangerous than turns, certainly a now outdated judgement. One wonders if anyone has designed a zeppelin to modern gust data and found that it could be built light enough to carry a viable payload?

#### PERFORMANCE AND ECONOMY

Economic cost formulations are published by governmental regulating agencies, although each manufacturer and user has his own rules as well. When government engages in a vast new engineering project it tends to make its own, new set of rules. It seems adequate at this time to make comparisons based on the weight of metal need to produce a given design, and the performance in terms of payload and range obtained by this investment.

TYPE	LZ-24 ● S.L. & H ●	LZ-85 100% purity	LZ-99	LZ-104	STAACKEN VI	LINKE HOFFMAN	LZ-129 MACON	AKRON 1931	DC-6 1947	BRISTOL BRITANNIA 1960
DATE	1914	1916	1917	1917	1917	1919	1936	1931	1947	1960
VOL. M cu ft	0.795	2.0	2.04	2.42	-	-	7.06	6.85	-	-
We M lbs	36.8	-	51.0	51.5	18.0	17.6	260.2	242.4	49.8	90.6
Wto M lbs	56.6	142.5	145.0	166.0	26.5	32.1	419.0	403.0	106.2	185.0
% We/Wto	65.2	-	35.2	31.1	68.0	54.7	62.6	60.3	46.8	49.0
PAYLOAD M lbs	0.7	5.0	9.9	26.5	2.2	-	36.4	30.0*	8.0	34.0
%PAYLOAD/Wto	1.24	3.51	6.83	16.0	8.24	-	8.01	-	7.5	18.4
CEILING M ft	1.5	15.0	19.0	1.5	19.4**	10.5	1.5	1.5	-	-
PASSENGERS							50		70	
CREW							50		7	

\*Estimated Airplane contingent

\*\*Adjustable pitch propellers

R = million

Figure 8. Design Data Comparisons

Fig. 8 shows data for a reasonable sample of airplanes and zeppelins from WWI forward. Because the data is obtained from so many different

sources, no real accuracy is claimed. It is felt that the figures are sufficiently representative for the task at hand. WWI data, with two exceptions, applies to bombing missions over England. Post WWII data applies to a minimum New York to Paris capability.

At first glance, it becomes apparent that there never was a 25 ton payload zeppelin, despite the almost daily assurances of Enthusiasts that such payloads are 'small' for zeppelins. The Enthusiasts and certain reference books alike, seem confused by the difference between "useful lift" and 'payload'. Next, the payload to gross lift ratio is little if any better than airplanes of the past, inferior to more recent airplanes and getting more inferior all the time.

The five WWI zeppelins show the influence of design altitude on the payload and range capabilities of a zeppelin. The first zeppelins were sea level designs. Antiaircraft fire soon drove them higher. The bomb loads peaked at 9,900 lbs with the LZ-99 of 1917, which had a design ceiling of 19,000 ft. The next example is the famed Bulgaria to Khartoum and return zeppelin, LZ-104 (L-59) which carried 26,500 lbs of supplies. The LZ-104 was a specially prepared LZ-99 type, with an extra lift bay added, increasing its volume by 18%. The great increase in payload and range was not due to extra lifting bay but that it flew a sea level route, while the LZ-99 at 19,000 ft was operating at a density ratio of .55. At that height LZ-99's lift was only 75,600 lbs, and her bomb load 13.5% of that. The LZ-104 with the same structure, was operating at sea level gross lift, -that is to say, grossly overloaded, for a one time flight.

The above possibly explains the tragedy of the L-72 (LZ-117?), of a class designed to operate at 26,400 ft (5000 meters), the peak development of German WWI zeppelins. Seized by France for 'reparations', named the DIXMUDE, she was used to surpass Germany's feat with the LZ-104, to impress the French African colonies by flying around them. The DIXMUDE was destroyed on the second such political exploit near Sicily, probably by structural failure in the vicinity of a storm, though she also burned in the air.

Designed to airline structural standards, the HINDENBURG (LZ-129) required 7 million cu ft to slightly exceed the feat of the LZ-104 with 2.4 million cu ft. To cross the United States in accordance with airline standards will require airships that many times larger again, to carry the same payload as the LZ-104.

Two WWI airplane designs appear in the figure. The Staaken VI bomb load in percentage of gross weight (% Payload/Wto) exceeded that of the Zeppelins. The Linke-Hoffman II, completed only after the war, is

shown in an overload condition. Its 54.7% empty to gross weight ratio (We/Wto) is the harbinger of airplane structural efficiency to come, - 20 years later. The Staaken Co. was a division of the Zeppelin Co., created by Count Zeppelin to produce bombing airplanes for the Army, because he never had any faith in the zeppelin employed as a bomber.

The figures presented for the HINDENBURG are not the more favorable ones representing hydrogen filling, but less favorable ones for helium at 95% purity and 1500 ft cruise altitude, which is the basis for the AKRON-MACON figures. The relatively small DC-6 is seen to be far superior in terms of structural ratio and almost matching the HINDENBURG in payload to weight ratio. The BRITANIA surpasses the HINDENBURG in both categories. The crew to passenger ratio alone may spell the difference between profit and loss for airline operations. The record is discouraging for any mode of transportation which demands a high level of manpower to operate.



Staaken E.4/20 all-metal airliner of 1920



Armstrong Whitworth ATALANTA class of 1932

Figure 9. Airplane Development Delay

Airplane-Airship Competition- Enthusiasts like to indulge in a theory that airplane interests conspired to delay the zeppelin progress. Figure 9 shows that an outstanding airplane development was seemingly suppressed for more than the number of years Germany was prohibited

from building large commercial zeppelins. The upper photo shows a Staaken passenger plane built of aluminum, equivalent in construction to the Boeing 247 and DC-3's of the 1930's, flown in 1921 before being ordered destroyed by the Allied Control Commission. The same design apparently resurfaced 12 years later on Imperial Airways, lower photo. So much for the conspiracy theory.

#### RANGE/PAYLOAD

The range payload curves of Fig. 10 complete the story. The BRITANNIA at 185,000 lbs almost encompasses the performance of zeppelins weighing  $2\frac{1}{2}$  times more. The 707-320, three quarters as heavy as the HINDENBURG, completely surpasses it. Because airplanes shown are 4 to 7 times faster than any airship ever built, and return of investment is dependent on productivity, the product of payload and speed, it is unnecessary to even show the relative speed or productivity of the airplane and the airship. This figure indicates the magnitude of the improvement necessary to produce zeppelins that will be economically viable, were they to ever overcome their operational difficulties.

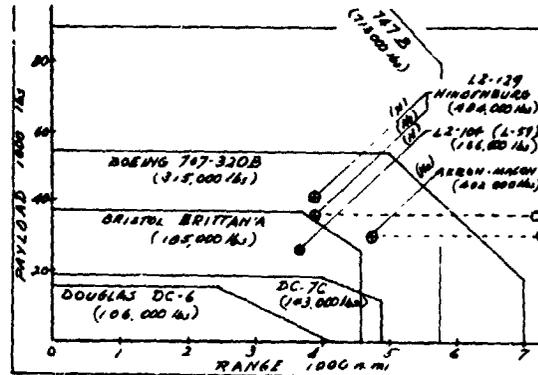


Figure 10.  
Range-Payload Comparisons

#### CONCLUSIONS

The Enthusiast recites like catechism that the advantage of the airship is that it requires no power to develop lift (unlike an airplane) and that this feature is its great advantage in economy and fuel savings over the airplane. This rote ignores the extreme weight empty penalty and high drag associated with the enormous gas filled structure required to produce bouyant lift, which inevitably defeats the airship in any comparison with the airplane in air commerce. But for the technological accident that large volumes of hydrogen became available to lift transatlantic payloads in bouyant aircraft a generation before large and reliable engines became available to lift those payloads in airplanes, the airship would never have been developed. It follows that when the engines became available the airship faded from the scene, and there appears no valid reason for ressurecting them as air carriers.

REPRODUCIBILITY OF THE  
ORIGINAL PAGE IS FOUR

The cathedral-like hangars which remain at Lakehurst and Moffett N.A.S. for one of man's most beautiful creations, the zeppelin, give pause for reflection of a brief chronicle of bouyant flight:

"The French Government of 1783, 'It is only a machine... which will some day prove serviceable to the wants of society'.

Sir George Cayley, in 1816, explaining why he was pursueing flight by means of inclined planes, '...my object was to leave out the unwieldy bulk of balloons altogether.'

Adm Wm A Moffett, USA, testifying before Congress, 'I would willingly sacrifice the purchase of one cruiser for two airships of the same cost, but would not sacrifice any airplane funds and transfer them to the airship fund...'

Sir Dennistoun Burney (in 1922 originator of the British Government's 'Burney Scheme' which resulted in producing the R-100 and R-101) writing in 1929, 'As a result of the last seven years investigation and work upon R-100, I am firmly convinced that airship enthusiasts not only overstated their case, but failed to realize that a vessel that could neither make a landing without elaborate extraneous aid, nor be housed or rigidly secured in rough weather, must always remain a doubtful value for commercial purposes.....'.

Hugo Eckener in his 1949 book, '...the role of this aerial vehicle in commerce seems to have ended after a brief period of glory....for speed and time saving are trump cards'".

Frank Lloyd Wright reportedly shook his head when he looked at St. Patrick's cathedral. Asked why he shook his head he answered that he approved of the design but not its purpose. That about sums up the case against the commercial carrier zeppelin.

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